

AD-064051

RIA-76-U551

~~CONFIDENTIAL~~

24402

AD 064651

*order  
back  
has*

*U-1828*

# FRANKFORD ARSENAL

USADACS Technical Library



5 0712 01004424 5

REPORT NO. R-1275



## TECHNICAL LIBRARY

PENETRATION PERFORMANCE OF 30 mm SOLID NOSE HE SHELL

PART I

REGRADED

*unclassified*

DA FORM 1575  
BY AUTHORITY OF: *std: 22 Nov 64*

*Frankford Arsenal*

ON

*25 Sep 67*

BY

J. R. Kymer and H. E. Fatzinger

PROJECT TS1-48

PITMAN-DUNN LABORATORIES

FRANKFORD ARSENAL

PHILADELPHIA, PA.

August 1955

Copy No. 45

~~CONFIDENTIAL~~



THIS REPORT HAS BEEN DELIMITED  
AND CLEARED FOR PUBLIC RELEASE  
UNDER DOD DIRECTIVE 5200.20 AND  
NO RESTRICTIONS ARE IMPOSED UPON  
ITS USE AND DISCLOSURE.

DISTRIBUTION STATEMENT A

APPROVED FOR PUBLIC RELEASE,  
DISTRIBUTION UNLIMITED.

UNCLASSIFIED

AD 64 651

CLASSIFICATION CHANGED

TO: UNCLASSIFIED

FROM: CONFIDENTIAL

AUTHORITY:

ARRADCOM Ltr

19 NOV 79



UNCLASSIFIED



```

-- 34 OF 38
-- 1 - AD NUMBER: 064651
-- 2 - FIELDS AND GROUPS: 19/1
-- 3 - ENTRY CLASSIFICATION: UNCLASSIFIED
-- 5 - CORPORATE AUTHOR: FRANKFORD ARSENAL PHILADELPHIA PA PITMAN-DUNN
-- RESEARCH LABS
-- 6 - UNCLASSIFIED TITLE: PENETRATION PERFORMANCE OF 30 MM SOLID NOSE
-- HE SHELL. PART I
-- 8 - TITLE CLASSIFICATION: UNCLASSIFIED
--10 - PERSONAL AUTHORS: KYMER, J.R.; FATZINGER, H.E.
--11 - REPORT DATE: AUG , 1955
--12 - PAGINATION: 27P MEDIA COST: $ 6.00 PRICE CODE: AA
--14 - REPORT NUMBER: R-1275
--20 - REPORT CLASSIFICATION: UNCLASSIFIED
--23 - DESCRIPTORS: *HIGH EXPLOSIVE AMMUNITION, PENETRATION,
-- PROJECTILES.
--24 - DESCRIPTOR CLASSIFICATION: UNCLASSIFIED
--25 - IDENTIFIERS: 30-MM ORDNANCE ITEMS.
--26 - IDENTIFIER CLASSIFICATION: UNCLASSIFIED
--33 - LIMITATION CODES: 1
--35 - SOURCE CODE: 283750
--36 - ITEM LOCATION: DTIC/NTIS
-- <<P FOR NEXT PAGE>> OR <<ENTER NEXT COMMAND>>

```

\*MSG RECEIVED\*

1a ROW=24 COL= 01

<Ctrl>H For Help

N Poll

~~CONFIDENTIAL~~

Initial distribution has been made of this report in accordance with the distribution list contained herein. Additional distribution without recourse to the Office, Chief of Ordnance, may be made to United States military organizations, and to such of their contractors as are certified to be cleared to receive this report and to need it in the furtherance of a military contract.

REGRADED Unclassified  
DA Form 1575  
BY AUTHORITY OF dtd: 22 NOV 66  
Frankford Arsenal  
ON 23 Sep 67

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

REPORT R-1275

PENETRATION PERFORMANCE OF 30 mm SOLID NOSE HE SHELL

PART I

Project TSI-48

Prepared by

J.R. KYMER  
Physicist

H.E. FATZINGER  
Chief  
Penetration Mechanics Branch

Reviewed by

G.C. WHITE, Jr  
Chief,  
Physics and Mathematics  
Division

H.W. EUKER  
Research Advisor  
Physics Research Laboratory

Approved by

W.J. KROEGER  
Director  
Physics Research Laboratory

C.C. FAWCETT  
Director  
Pitman-Dunn Laboratories Group

For

JOSEPH M. COLBY  
Brigadier General, USA  
Commanding

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

#### ACKNOWLEDGMENT

The authors wish to thank Mr. Sidney Ross and Mr. Stephen Kucsan of the Ballistics Division of the Pitman-Dunn Laboratories for their cooperation and guidance in the interior ballistics and original design phases of this work.

~~CONFIDENTIAL~~

**CONFIDENTIAL**

TABLE OF CONTENTS

|  | Page |
|--|------|
| INTRODUCTION                                 | 1    |
| MATERIALS AND METHODS                        | 3    |
| Composition and Heat Treatment . . . . .     | 3    |
| Rotating Bands . . . . .                     | 5    |
| Plate. . . . .                               | 5    |
| Firing . . . . .                             | 7    |
| Evaluation Using High-speed X-rays . . . . . | 7    |
| RESULTS AND DISCUSSION                       | 7    |
| Model 1. . . . .                             | 7    |
| Model 2 and 3 . . . . .                      | 11   |
| Model 4. . . . .                             | 16   |
| CONCLUSIONS. . . . .                         | 26   |
| FUTURE WORK . . . . .                        | 26   |
| RECOMMENDATIONS . . . . .                    | 26   |
| Distribution . . . . .                       | 27   |

**CONFIDENTIAL**



~~CONFIDENTIAL~~

## OBJECT

To develop a 30 mm thin-walled, base fuze, HEI shell which has optimum target penetration characteristics.

## SUMMARY

A solid nose, based fuze 30 mm shell has been designed which is at least twice as effective for penetration as the present nose fuze design (T306) against 60° and 70° obliquity aluminum armor targets, and which practically satisfies the ultimate penetration requirements. It is possible for this shell to remain intact after defeating 3/4 inch 24S-T4 aluminum alloy plate between 45° and 70° obliquities, and 5/8 inch plate from 0° to 75° obliquities at velocities of 2800 to 3000 fps. This shell, however, only partially meets the requirements of weight, explosive capacity, and exterior contour. Modifications of the present inert loaded design are being made to fulfill the specified requirements.

It is recommended that the blunt nosed principle of design be considered for other types of HE and small arms armor piercing ammunition.

## AUTHORIZATION

OCM C663, FA 47/1952, 00 471./91/8 (S)

Minutes of Sixth Aircraft Ammunition Conference at Aberdeen Proving Ground, 5 and 6 May 1953, 00, ORDTS

~~CONFIDENTIAL~~

## INTRODUCTION

It has been found<sup>(1)</sup> that, in order to obtain effective blast damage on aircraft structures with HEI ammunition, the projectile must remain intact after penetration of the surface so that high order detonation of the explosive occurs inside the aircraft structure. The present interim 30 mm HEI shell (T306E10) (Figure 1) under development for Air Force use remains intact after defeating up to 1/4 inch 24S-T4 aluminum alloy plate at 60° obliquity. The original Air Force requirement was the defeat of targets up to 5/8 inch plate at 80° obliquity. However, the urgency of procurement of combat rounds for early use necessitated the acceptance of reduced "interim" performance. On a reduced priority basis, studies were conducted in an attempt to provide the higher level of performance.

This is a partial report on a program undertaken to develop a shell capable of the higher level of performance, which will have the following characteristics:

|                               |                                |
|-------------------------------|--------------------------------|
| Projectile weight (with fuze) | 3900 gr max                    |
| HE filler weight              | 750 gr ( $\Delta = 2.0$ gm/cc) |
| Muzzle velocity               | 2800 to 3000 fps               |
| Exterior contour              | Match T306 HEI projectile      |
| Chamber pressure              | 40,000 psi (Cu) max, avg       |

It was believed that the higher performance could be obtained if the front of the shell were solid and if a suitable base fuze were provided. Therefore, a project was undertaken to develop a base fuze shell.

From penetration studies<sup>(2,3)</sup> performed with 20 mm armor piercing solid steel projectiles, it is known that a flat or blunt nosed projectile can bite in and defeat high obliquity thin steel targets at much lower velocities than conventional nosed projectiles. Also, against high obliquity targets, flat nosed projectiles can remain intact at higher velocities than conventional projectiles.

- 
1. J. N. Sermousakis, "Report on Tests of the Effect of Blast from Bare and Cased Charges on Aircraft," Aberdeen Proving Ground BRL Memo Report 436, 1 July 1946.
  2. H. W. Euker and C. W. Curtis, "Design of Armor Piercing Projectiles for High Angle Attack," Frankford Arsenal Report R-1070, June 1952.
  3. J. R. Kyser and H. E. Fetzsinger, "Solid Steel AP Projectiles - Conventional, Truncated, and Tipped Truncated Ogive Types," Frankford Arsenal Report R-1166, October 1953.

~~CONFIDENTIAL~~



Figure 1. Interim 30 mm HEI shell

~~CONFIDENTIAL~~

## MATERIALS AND METHODS

### Composition and Heat Treatment

The shell used were made of SAE 1137 and SAE 1045 steels. The shell of SAE 1137 steel were austenitized at 1550° F, quenched in oil, and then tempered at 250°, 400°, 600°, and 800° F.

Model 1 shell of SAE 1045 steel were austenitized at 1650° F, quenched in oil, and then tempered at 250° F ( $R_C$  42), 400° F ( $R_C$  38), 600° F ( $R_C$  34), and 800° F ( $R_C$  30). Model 2, 3, and 4 shell of SAE 1045 steel were austenitized at 1550° F, quenched in brine, and tempered at 300° F ( $R_C$  56), 375° F ( $R_C$  52), 450° F ( $R_C$  47), and 500° F ( $R_C$  42). Steels and hardnesses for the different designs are listed in Table I.

Table I. Material and Hardness of Steel Tested

| Model | Steel | Approximate Hardness ( $R_C$ ) |
|-------|-------|--------------------------------|
| 1A    | 1137  | 42, 38, 30, 27                 |
| 1B    | 1045  | 42, 38, 34, 30                 |
| 2A    | 1137  | 42                             |
| 2B    | 1045  | 47, 42                         |
| 3A    | 1137  | 42                             |
| 3B    | 1045  | 47                             |
| 4     | 1045  | 56, 52, 47, 42                 |

All shell were inert loaded with IM 110 inert mix, which simulates the explosive filler to be used, and had aluminum base plugs (Figure 2) in lieu of the base fuzes being developed for this shell. Weights of the various components, with the shell capacities, are listed in Table II.

Table II. Weights of Components and Shell Capacities

| Model | Weight of<br>Body<br>(gm) | Weight of<br>Base Plug<br>(gm) | Weight of<br>Inert Filler<br>(gm) | Total<br>Weight<br>(gm) | Capacity<br>(cc) |
|-------|---------------------------|--------------------------------|-----------------------------------|-------------------------|------------------|
| 1     | 2150                      | 310                            | 700                               | 3160                    | 22.8             |
| 2     | 2790                      | 310                            | 785                               | 3885                    | 22.8             |
| 3     | 2850                      | 310                            | 785                               | 3945                    | 22.8             |
| 4     | 2940                      | 445                            | 655                               | 4040                    | 19.4             |

~~CONFIDENTIAL~~



~~CONFIDENTIAL~~

Neg. #26240-2

R-1275

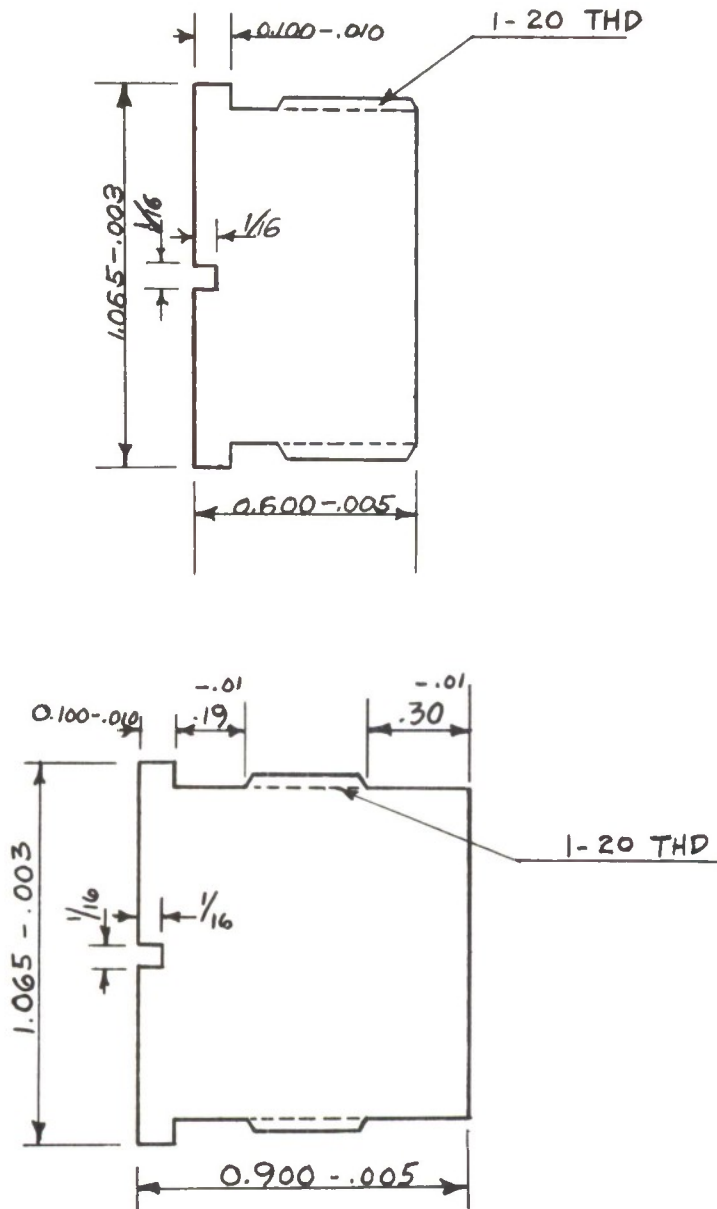


Figure 2. Aluminum Base plugs

Upper - Models 1, 2, 3

Lower - Model 4

~~CONFIDENTIAL~~

## Rotating Bands

All of the thin walled shell described in this report had welded copper overlay bands. Had these shell had regular band seats, they could not have withstood the swaging forces necessary to seat conventional bands. Even if banding had been achieved by providing internal support, the shell would have collapsed upon firing. Because of the failure of thin walled shell with conventional rotating bands, a new type of rotating band was conceived and developed by Pitman-Dunn Laboratories Group of Frankford Arsenal. The new bands, called "welded overlay rotating bands," are applied directly on the full diameter base section of the shell, thus eliminating the band seat. The overlay band is applied before heat treating. The heat treatment serves as an anneal which is necessary both for machining purposes and for proper functioning as a rotating band.

The bands are machined from welded overlays deposited circumferentially on the projectile by the inert-gas-shielded metal-arc welding process. This process employs a bare wire electrode which is continuously fed and consumed. This adaptation of conventional welding has favorably approached the advanced states of controlled procedures and ballistic studies, not only on this shell, but also on projectiles in sizes ranging from caliber .50 to 280 mm.

Some of the advantages of the welded overlay band are:

- (1) The band becomes an integral part of the projectile because of the fusion bond, thus eliminating the possibility of the band becoming loose or separating from the projectile during its flight.
- (2) No band seat is required. This permits the use of thin walled shell with increased explosive capacity.
- (3) The occurrence of quench cracks is reduced.
- (4) Favorable and uniform ballistic performance is obtained.

## Plate

All firings were conducted against various thicknesses of commercial 24S-T4 aluminum plate at obliquities of 0, 30, 45, 55, 60, 65, 70, and 80 degrees. The plates were held rigidly in a mount (Figure 3) designed specially to enable high-speed radio-graphs to be taken of the projectiles either before, during, or after penetration, and to permit accurate adjustment of the angle of obliquity.

~~CONFIDENTIAL~~

## Firing

All rounds were fired from a 30 mm Mann type barrel. Velocities were measured over a ten-foot base line by a counter chronograph actuated by breaking printed circuits.

## Evaluation Using High-speed X-rays

High-speed X-ray pictures were taken of all rounds after they had penetrated the plate. From examination of the X-ray negative, it is possible to determine whether or not the shell remained intact without the delay and the work necessary in recovering high velocity projectiles in some medium that should not produce any additional deformation or rupture. Furthermore, the extent and location of deformation can be noted and, by proper selection of targets, the region of initiation of failure can be determined. After these observations have been made over a range of obliquities, it is possible to make design modifications which will increase the shell effectiveness.

The X-rays were taken with a unit originally designed by Westinghouse Electric Co. in conjunction with this arsenal, for use in terminal ballistic studies. The unit consists of a control unit, high voltage rectifier unit, surge generator, and an X-ray tube (Figure 4).

A Micronex interval timer is used in conjunction with the high-speed X-ray unit to insert, electronically, a preselected time interval between the initiation of the timing cycle and triggering of the surge generator. The projectile breaks a printed circuit, which initiates the timing cycle. After a selected time, the surge generator is discharged, giving an impulse of up to 360,000 volts to the X-ray tube. For the radiographs shown in this report, an impulse of 300,000 volts was used. The X-ray tube was placed five feet from the line of flight of the shell, and the cassette three inches from the line of flight.

## RESULTS AND DISCUSSION

### Model I

A sketch of the first design is shown in Figure 5. A double conical nose shape was chosen from experimental results obtained with solid 20 mm AP projectiles against homogeneous steel targets.<sup>(3)</sup> It was observed that, against high obliquity targets,

---

3. Ibid

~~CONFIDENTIAL~~

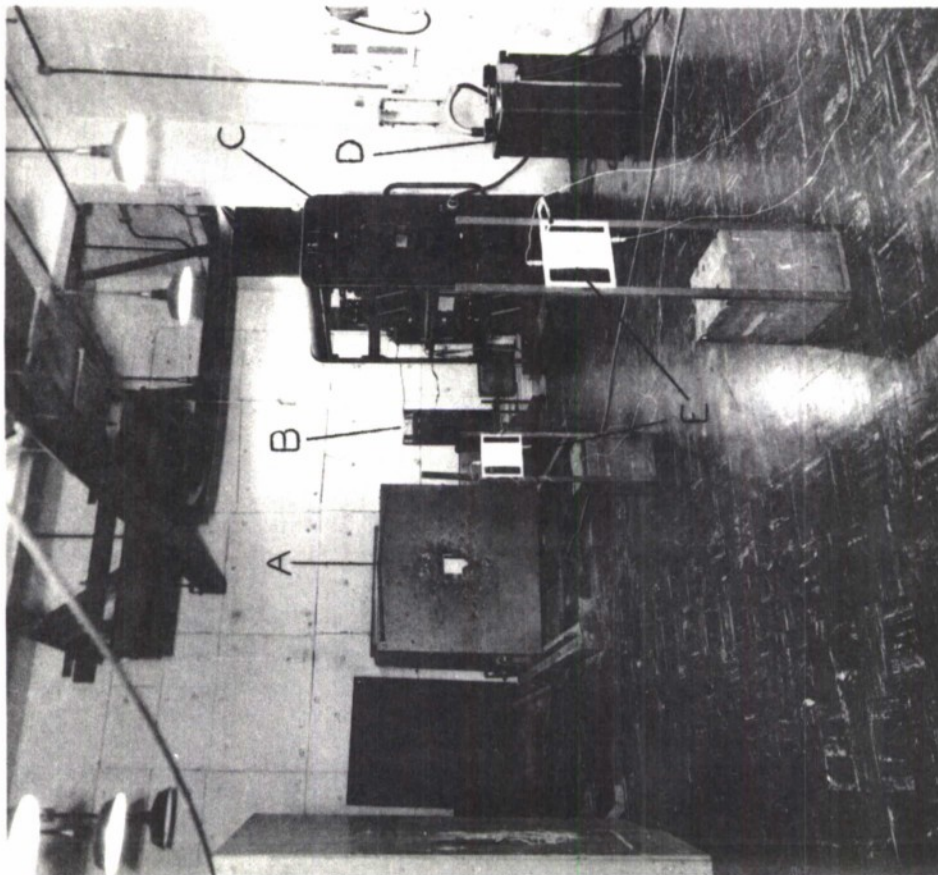


Figure 4. X-ray range setup

- A - Fragment protection box
- B - X-ray tube (in oil)
- C - Surge generator
- D - Rectifier unit
- E - Velocity screens

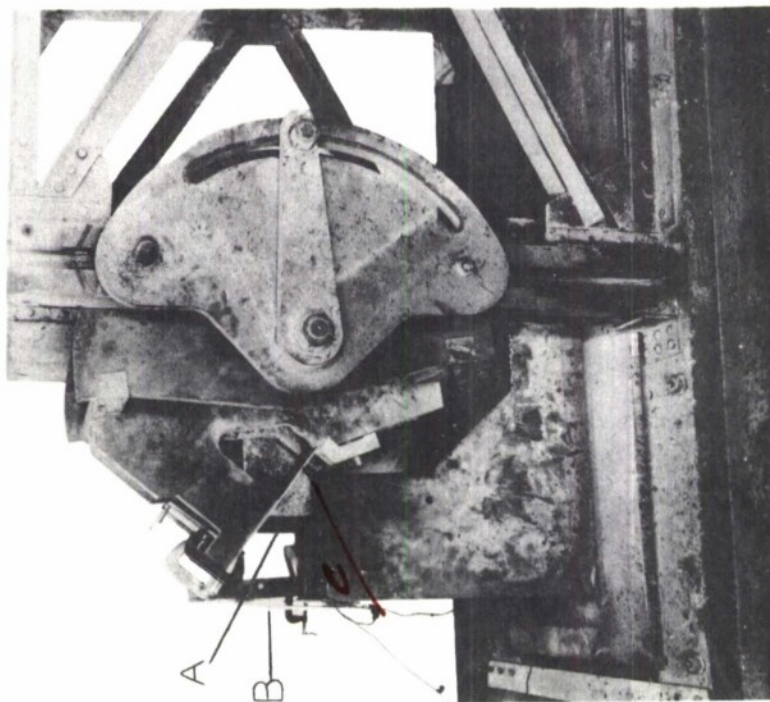


Figure 3. Plate mount with fragment protection  
box removed

- A - Cassette
- B - X-ray triggering screen
- C - Plate



**CONFIDENTIAL**

8



Figure 5. 30 mm HE shell, Model I, prior to application of welded band

**CONFIDENTIAL**

a flat nosed cylindrical projectile would remain intact at higher velocities than projectiles with conventional nose shapes. Furthermore, a flat nosed projectile with a tapere biting edge<sup>(2)</sup> remains intact at even higher striking velocities.

The "flat" portion of the shell was tapered to give more protection at low angles of attack. Under these conditions, the sharper the nose, the higher will be the velocity at which the projectile ruptures.

This model was made from both 1137 and 1045 steels. The 1137 steel was used since it was being used for engineering test lots. The 1045 steel was included since it can be hardened to a higher value than the 1137 steel. Groups of shell made from both steels were tempered at 250°, 400°, 600°, and 800° F to evaluate the effect of hardness on performance.

The shell ~~was~~ <sup>were</sup> fired against 1/4, 3/8, and 1/2 inch plate at 60° obliquity and against 3/8 inch plate at 0° obliquity at velocities of 2560 to 2700 fps. As may be noted in Table III, the performance of all the shell was poor. X-rays of the two rounds which remained intact, but deformed considerably, are shown in Figure 6. (Some detail has been lost in reproduction of prints from the original X-ray negatives.)

Since the nose portion of the shell was deformed to a great extent in the 60° firing, it was decided to strengthen this section by increasing its thickness.

Table III. Summary of Results for Model I Shell

| Target             |                    | Steel* | Hardness<br>R <sub>C</sub> | Striking<br>Velocity<br>(fps) | Condition<br>of<br>Projectile  |
|--------------------|--------------------|--------|----------------------------|-------------------------------|--------------------------------|
| Thickness<br>(in.) | Obliquity<br>(deg) |        |                            |                               |                                |
| 1/2                | 60                 | A      | 30                         | 2635                          | Fracture                       |
|                    | 60                 | A      | 38                         | 2652                          | "                              |
|                    | 60                 | B      | 30                         | 2558                          | "                              |
|                    | 60                 | B      | 42                         | 2639                          | "                              |
|                    | 0                  | B      | 42                         | 2660                          | "                              |
|                    | 0                  | A      | 42                         | 2703                          | "                              |
| 3/8                | 60                 | A      | 34                         | 2625                          | "                              |
|                    | 0                  | A      | 34                         | 2584                          | "                              |
|                    | 0                  | A      | 30                         | 2660                          | "                              |
|                    | 0                  | B      | 30                         | 2639                          | Intact, very<br>large swell    |
| 1/4                | 60                 | A      | 34                         | 2652                          | Fracture                       |
|                    | 60                 | A      | 42                         | 2667                          | "                              |
|                    | 60                 | B      | 27                         | 2611                          | "                              |
|                    | 60                 | B      | 38                         | 2625                          | "                              |
|                    | 60                 | B      | 42                         | 2611                          | Intact,<br>badly de-<br>formed |

\*A - 1137 steel; B - 1045 steel

2. Ibid

**CONFIDENTIAL**

~~CONFIDENTIAL~~

Neg. #26240-5  
R-1275

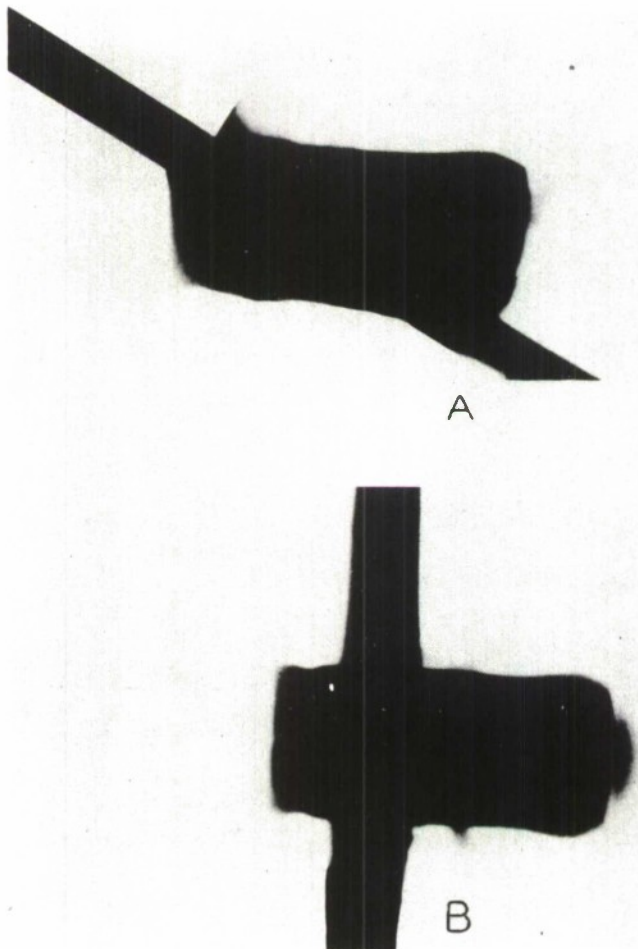


Figure 6. High-speed radiographs of Model IB ( $R_C$  34) intact shell

A -  $1/4$  inch at  $60^\circ$ , 2611 fps  
B -  $3/8$  inch at  $0^\circ$ , 2639 fps

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

### Models 2 and 3

Sketches of Models 2 and 3 are shown in Figures 7 and 8. Model 2 has the same contour as Model 1, except for the addition of 0.300 inch of steel at the nose of the shell. Model 3 is the same as Model 2, except that the biting edge has not been tapered. It was believed that Model 3 would be more efficient in penetration and that the additional resistance to deformation at the biting edge (which a double conical shape provides) might not be necessary since the target is aluminum. The two models were made from both 1137 and 1045 steels. The 1137 steel was hardened to  $R_C$  42 and the 1045 steel was hardened to  $R_C$  42 and  $R_C$  47.

The target conditions and a summary of the firing results are given in Table IV. All rounds were fired at velocities of 2785 to 2880 fps. The most effective design used in this series was Model 2B ( $R_C$  47) which was the only one capable of remaining intact after defeating 5/8 inch plate at  $60^\circ$  obliquity.

Table IV. Summary of Results for Models 2 and 3  
Fired at Velocities of 2785 to 2880 fps

| Target          |                 | No. of Rounds | Model No. | Steel* | Hardness $R_C$ | Condition of Projectile  |
|-----------------|-----------------|---------------|-----------|--------|----------------|--------------------------|
| Thickness (in.) | Obliquity (deg) |               |           |        |                |                          |
| 3/4             | 45              | 1             | 2         | A      | 42             | Fracture                 |
|                 | 45              | 1             | 2         | B      | 47             | No picture               |
|                 | 0               | 1             | 2         | B      | 47             | Fracture                 |
| 5/8             | 65              | 2             | 2         | B      | 47             | 1-fracture;<br>1-intact  |
|                 | 60              | 2             | 2         | B      | 47             | Intact,<br>large swell   |
|                 | 60              | 2             | 2         | B      | 42             | Fracture                 |
|                 | 60              | 2             | 3         | B      | 47             | Fracture,<br>large swell |

\*A - 1137 steel; B - 1045 steel

~~CONFIDENTIAL~~



Neg. #26240-6  
R-1275

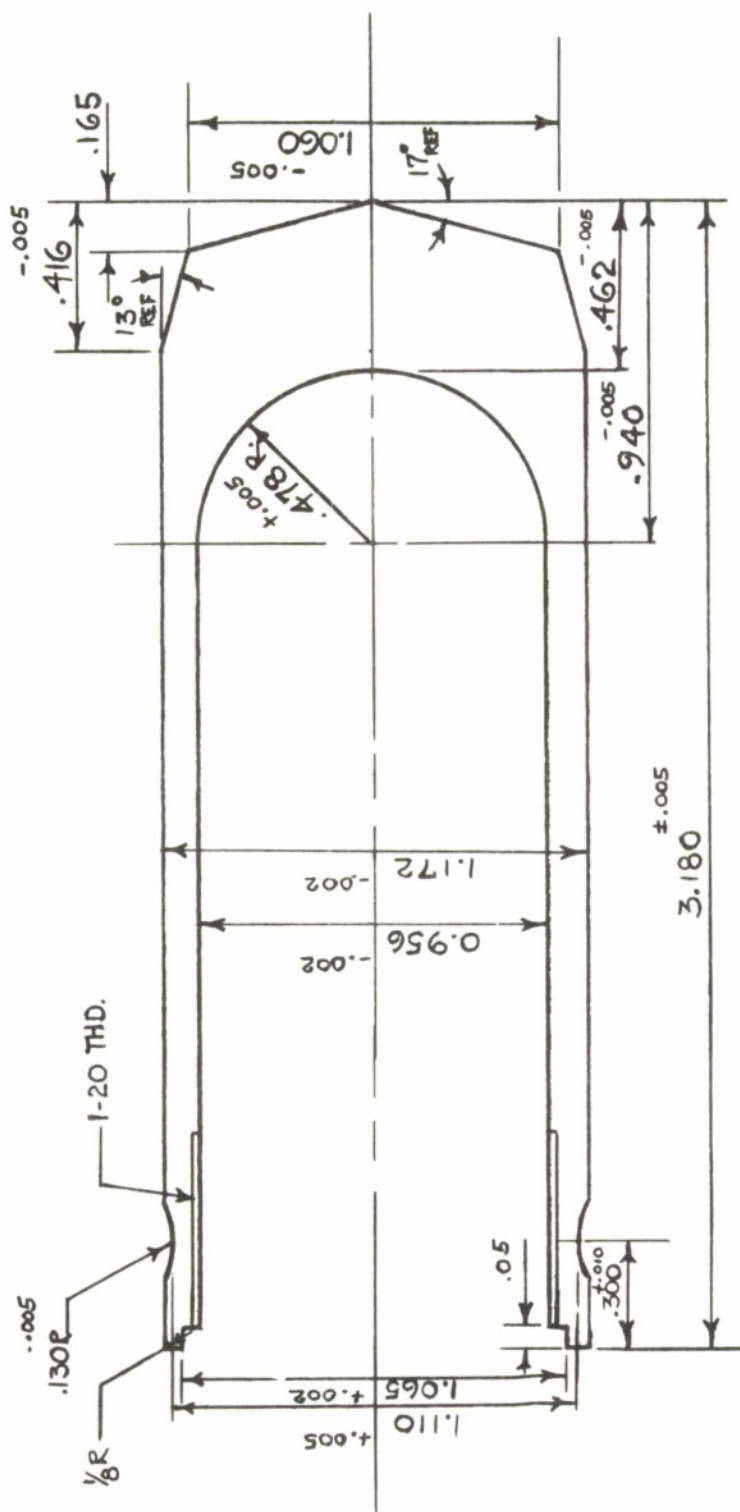


Figure 7. 30 mm HE shell, Model 2, prior to banding

Neg. #26240-7  
R-1275

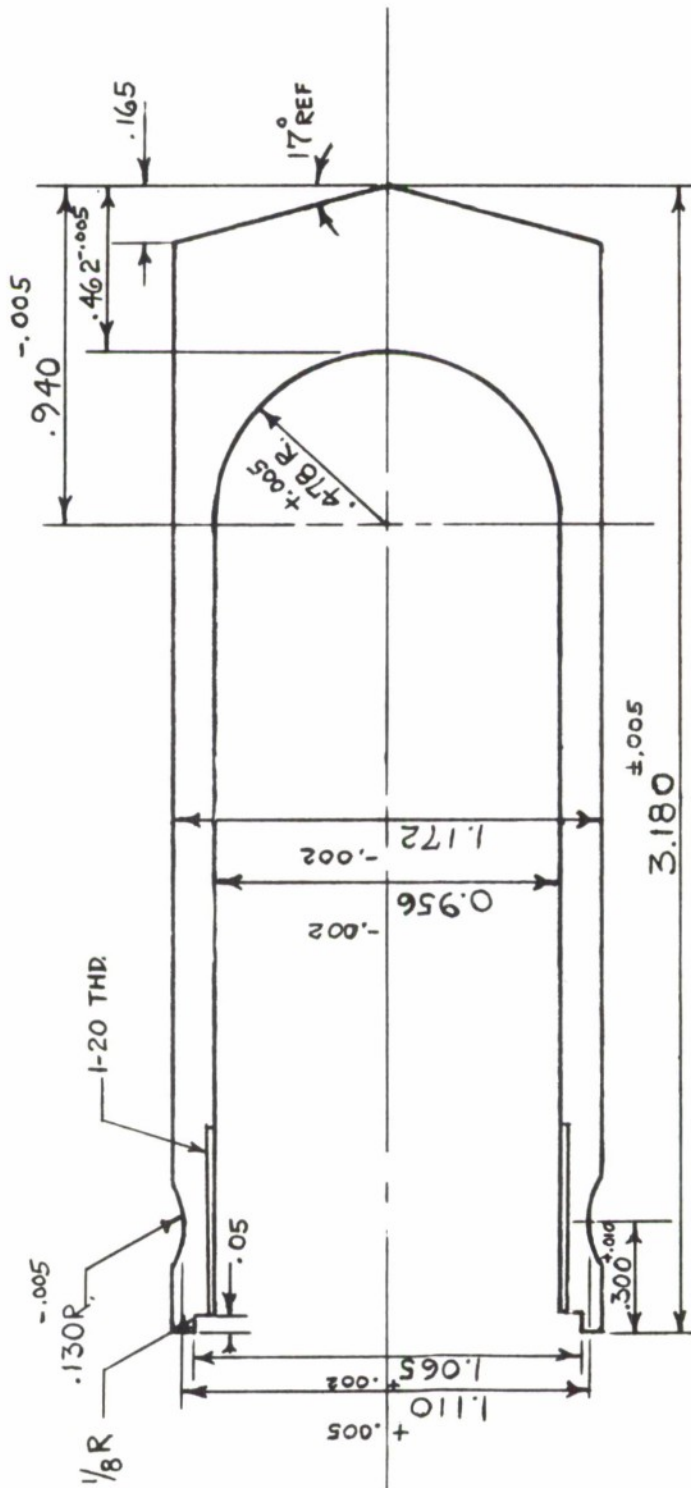


Figure 8. 30 mm HE shell, Model 3

Table IV. Summary of Results for Models 2 and 3  
Fired at Velocities of 2785 to 2880 fps (Cont'd)

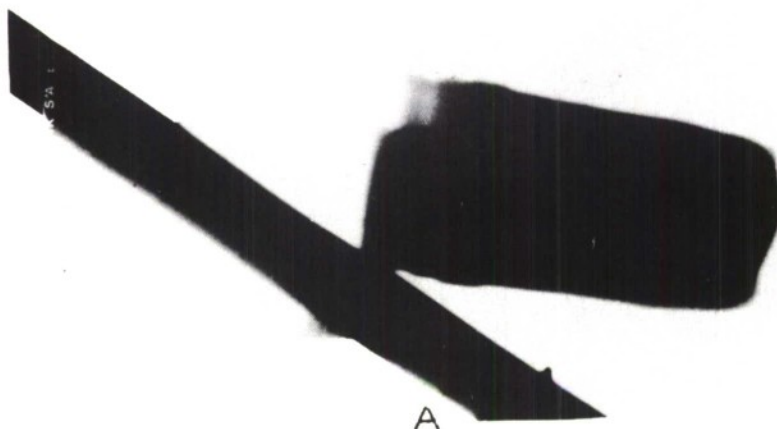
| Target             |                    | No. of<br>Rounds | Model<br>No. | Steel* | Hardness<br>R <sub>C</sub> | Condition<br>of<br>Projectile                                     |
|--------------------|--------------------|------------------|--------------|--------|----------------------------|---|
| Thickness<br>(in.) | Obliquity<br>(deg) |                  |              |        |                            |   |
| 1/2                | 65                 | 3                | 2            | B      | 47                         | 2 - intact, swell;<br>1 - fracture                                |
|                    | 60                 | 1                | 2            | B      | 47                         | Intact, swell   |
|                    | 60                 | 2                | 2            | B      | 42                         | Intact, large swell   |
|                    | 60                 | 2                | 3            | B      | 47                         | Intact  |
|                    | 60                 | 4                | 2            | A      | 42                         | 1 - intact, large swell;<br>3 - fracture, longitu-<br>dinal split |
|                    | 60                 | 2                | 3            | A      | 42                         | Fracture  |
|                    | 0                  | 2                | 2            | B      | 47                         | Intact, swell   |
|                    | 0                  | 1                | 2            | B      | 42                         | Ditto   |
|                    | 0                  | 1                | 3            | B      | 47                         | Ditto   |
|                    | 0                  | 3                | 2            | A      | 42                         | 1 - intact, large swell;<br>2 - longitudinal split                |
|                    | 0                  | 1                | 3            | A      | 42                         | Longitudinal split  |
|                    | 70                 | 1                | 2            | B      | 47                         | Intact, very slight<br>swell                                      |
|                    | 70                 | 2                | 2            | A      | 42                         | Intact, slight swell  |
|                    | 65                 | 3                | 2            | A      | 42                         | Ditto   |
|                    | 60                 | 1                | 2            | B      | 42                         | Intact, swell   |
| 3/8                | 60                 | 1                | 3            | B      | 47                         | Ditto   |
|                    | 60                 | 2                | 2            | A      | 42                         | Intact, no swell  |
|                    | 60                 | 2                | 3            | A      | 42                         | 1 - intact, large swell;<br>1 - fracture                          |
|                    | 0                  | 1                | 3            | A      | 42                         | Fracture  |

\*A - 1137 steel; B - 1045 steel

High-speed radiographs of typical failures of shell made of the different steels are given in Figure 9. The shell of 1137 steel usually split longitudinally with the crack extending to the point of the shell (Figure 9A) while the shell made of 1045 steel cracked at right angles to the axis where the inside radius becomes tangent to the inside diameter. Longitudinal cracking may be due to longitudinal sulphur stringers

~~CONFIDENTIAL~~

Neg. #26240-8  
R-1275



A



B



C

Figure 9. High-speed radiographs of typical failures of Model 2 and 3 fractured shell

- A - Model 2A (Rc 42), 1/2 inch at 60°, 2841 fps
- B - Model 2B (Rc 42), 5/8 inch at 60°. 2801 fps
- C - Model 3B (Rc 47), 5/8 inch at 60°. 2833 fps

~~CONFIDENTIAL~~



~~CONFIDENTIAL~~

which sometimes are present in 1137 steel. These stringers are zones of weakness and provide paths for crack propagation. Because of these stringers, this steel is no longer considered acceptable for HE shell.

Model 3B shell did not fail in the nose section, but failed in the same manner as did Model 2B (Figure 9C); therefore, the inferiority of these shell is not due to the weakness of the biting edge. For Model 3B there is a larger area that is loaded in the beginning of penetration, and this transmits a larger force to the body.

While Model 2B was quite effective, a study of Figures 9B and 10 indicates further possible improvements. The shell failed at the region of maximum swell, which is just rearward of the point of tangency of the inner radius. Therefore, Model 4 was designed to give greater wall thickness in the region where Model 2 failed.

#### Model 4

A sketch of Model 4 is given in Figure 11. The outside contour of this shell is the same as that of Model 2, while the inside contour is similar to a conventional ogive.

All shell of Model 4 were made from 1045 steel. Groups of the shell were tempered to  $R_c$  hardnesses of 56, 51, 46, and 40. A summary of the firing is given in Table V.

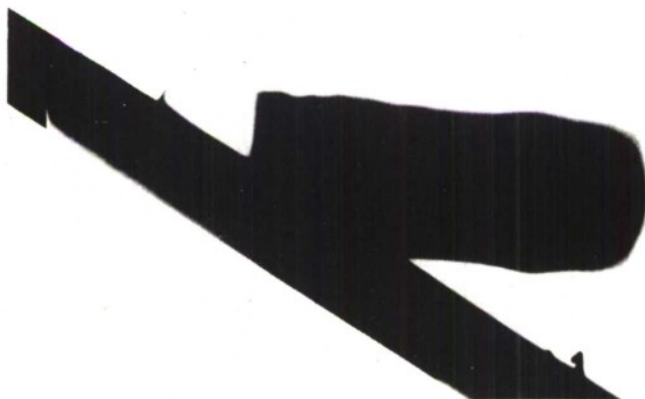
This design (Model 4) could remain intact in defeating 3/4 inch plate between  $45^\circ$  and  $70^\circ$  obliquities ( $30^\circ$  and  $75^\circ$  obliquities were not investigated), and 5/8 inch plate from  $30^\circ$  to  $75^\circ$  obliquities. Only the softest shell could defeat 5/8 inch plate at  $0^\circ$  obliquity without fracturing; the hardest ones could not defeat 1/2 inch plate at  $0^\circ$  without fracturing. None of the shell could perforate 1/2 inch plate at  $80^\circ$  obliquity.

Sample X-ray photographs of the 3/4 inch plate firings are given in Figures 12 and 13, and of the 5/8 inch plate firings in Figures 14, 15, and 16. For both targets, the deformation of the shell decreased with increasing obliquity. At low obliquity, the softer shell deformed more; however, due to their greater ductility, they were able to undergo more extensive deformation without rupturing. The rounds at  $75^\circ$  obliquity were turned considerably (approximately parallel to the plate) after perforating the target.

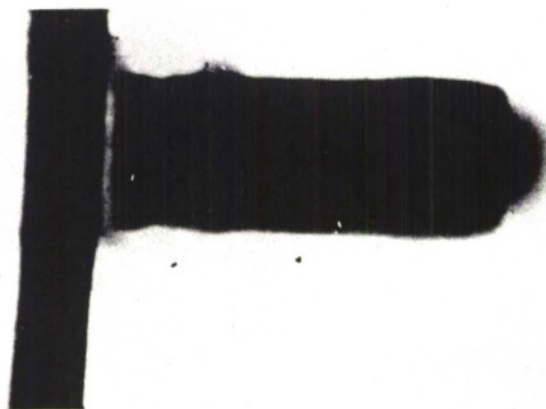
X-ray photographs of the 1/2 inch plate firing are given in Figure 17. As against 5/8 inch plate, the softer shot were better at normal obliquity. At  $80^\circ$  obliquity, the shell punched a large hole through the plate, but ricocheted intact. At the moment the X-ray was taken, the base of the shell was through the plate.

~~CONFIDENTIAL~~

Neg. #26240-9  
R-1275



A



B

Figure 10. High-speed radiographs of Model 28 intact shell

- A - RC 47 vs  $5/8$  inch at  $60^\circ$ , 2800 fps
- B - RC 42 vs  $1/2$  inch at  $0^\circ$ , 2833 fps

~~CONFIDENTIAL~~

Neg. #26240-10  
R-1275

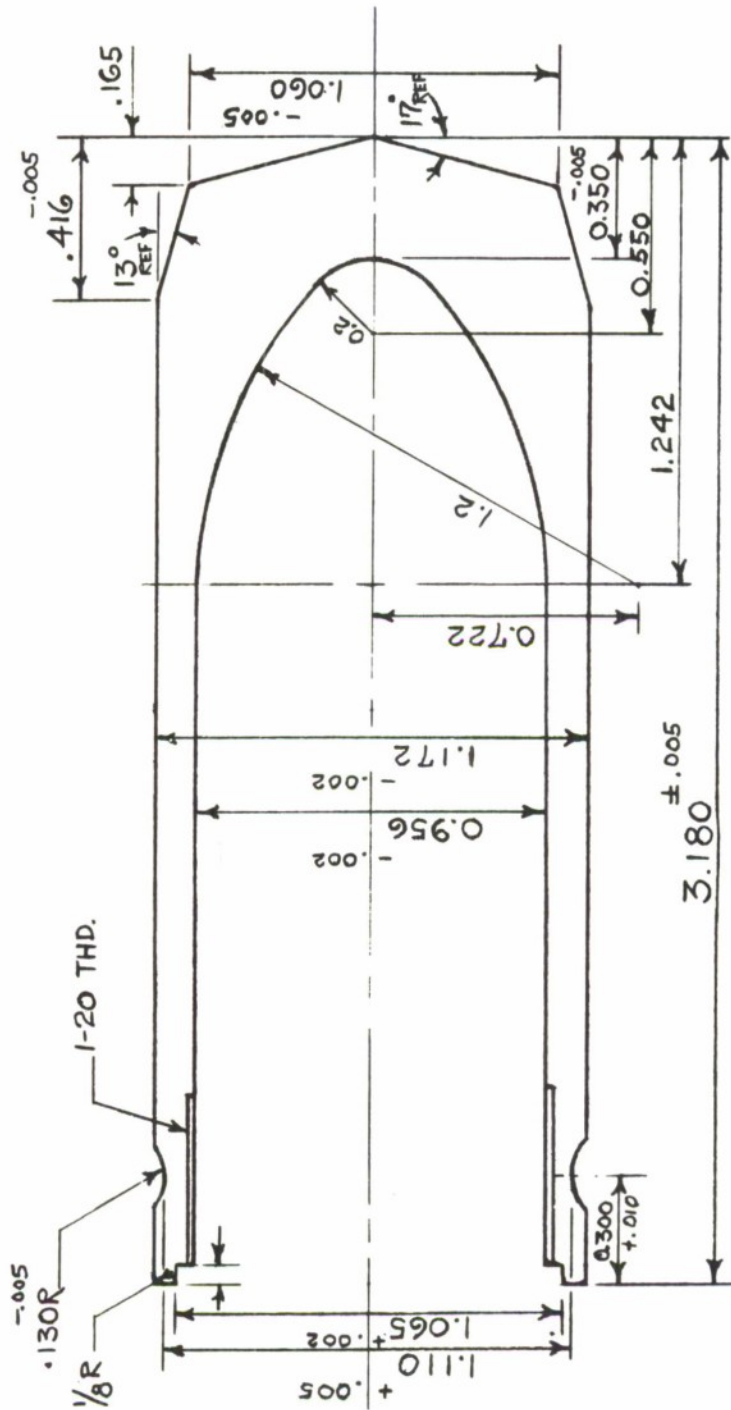
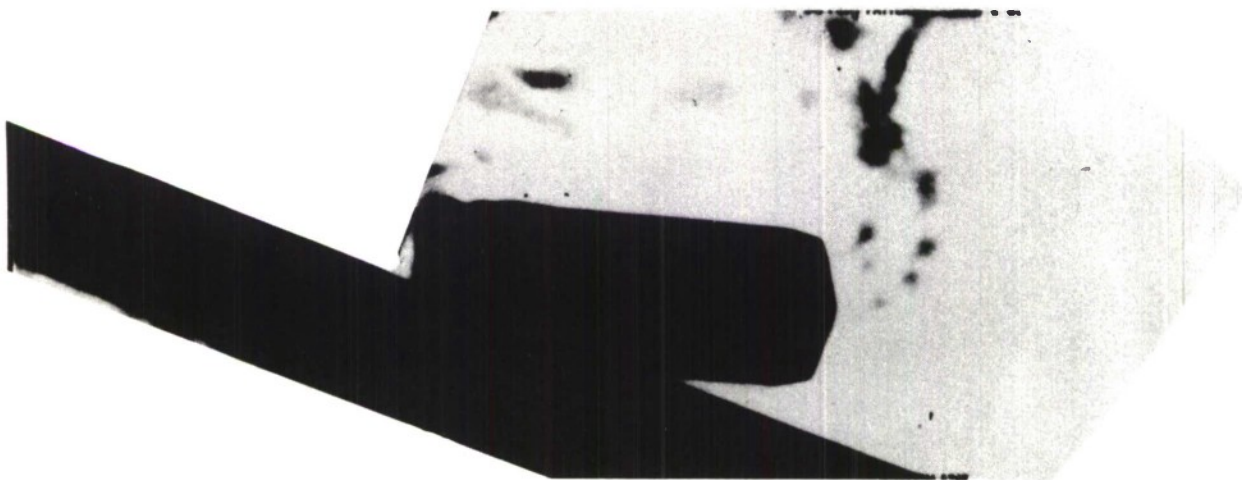


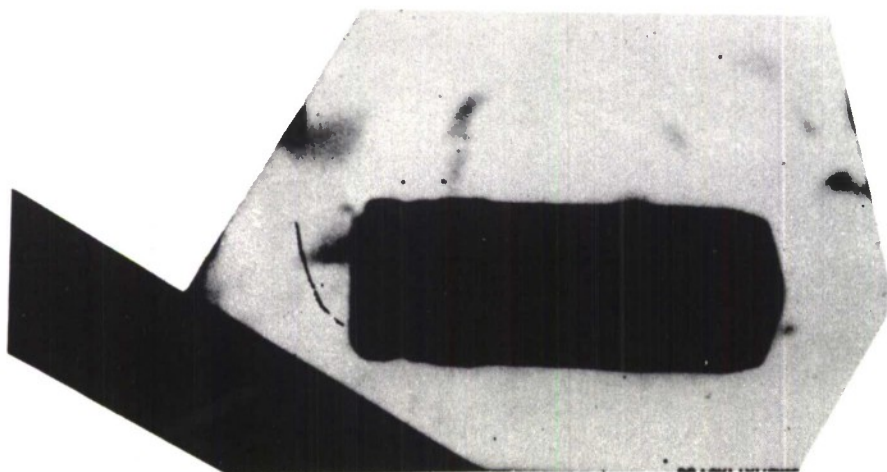
Figure 11. 30 mm HE shell, Model 4

~~CONFIDENTIAL~~

Neg. #26240-11  
R-1275



A



B

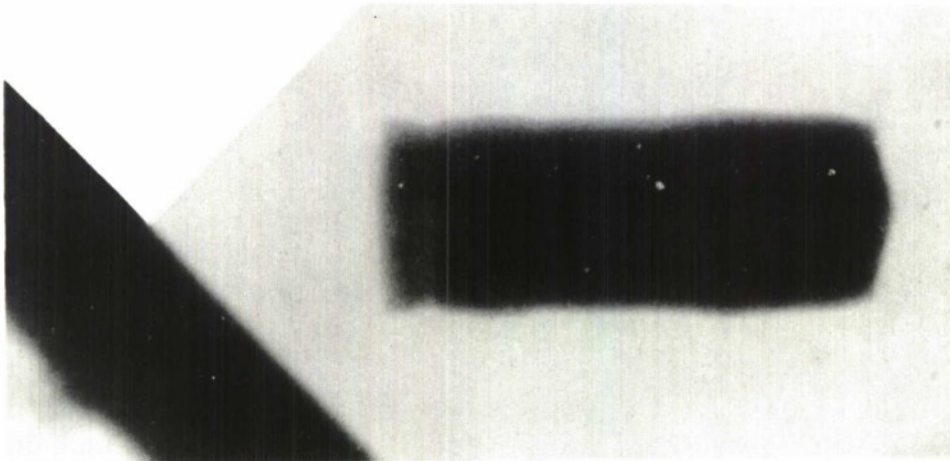
Figure 12. High-speed radiographs of Model 4 (R<sub>C</sub> 56) intact shell  
vs 3/4 inch plate

A - At 70°, 2907 fps  
B - At 60°, 2899 fps

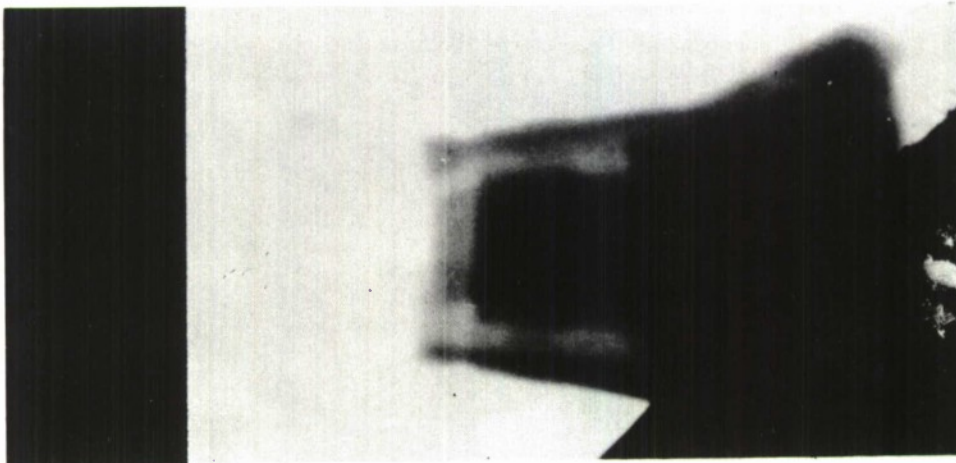
~~CONFIDENTIAL~~



Neg. #26240-12  
R-1275



A



B

Figure 13. High-speed radiographs of Model 4 (Rc 46) shell vs  
3/4 inch plate

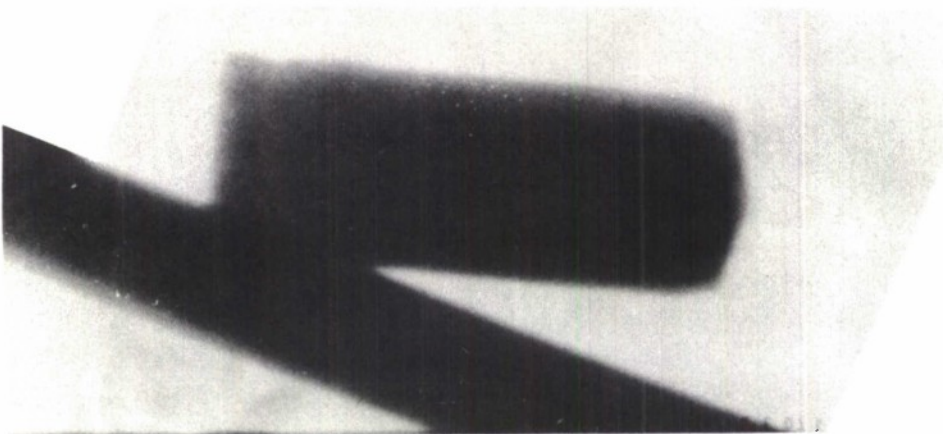
A - Intact, at 45°, 2907 fps  
B - Fracture, at 0°, 2937 fps

~~CONFIDENTIAL~~

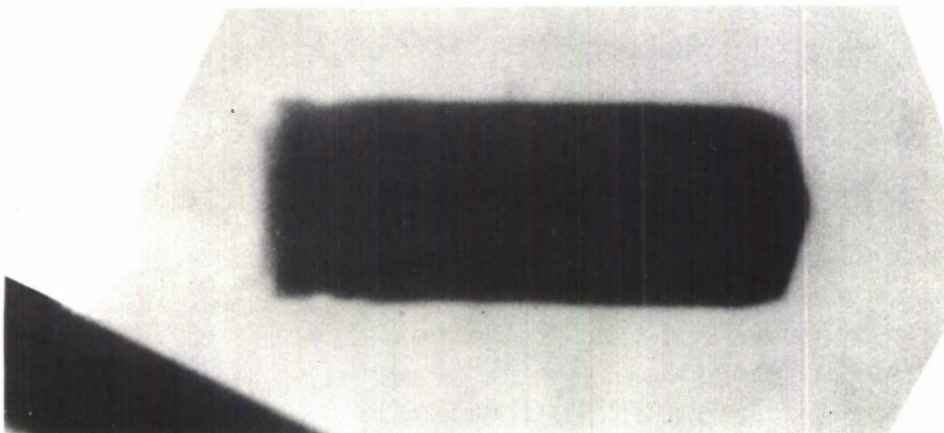
Neg. #25240-13  
R-1275



A



B



C

Figure 14. High-speed radiographs of Model 4 intact shell vs  
5/8 inch plate

- A - Model 4 ( $R_C$  56), at  $75^\circ$ , 2899 fps
- B - Model 4 ( $R_C$  46), at  $70^\circ$ , 2933 fps
- C - Model 4 ( $R_C$  56), at  $65^\circ$ , 2950 fps

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

Neg. #26240-14

R-1275

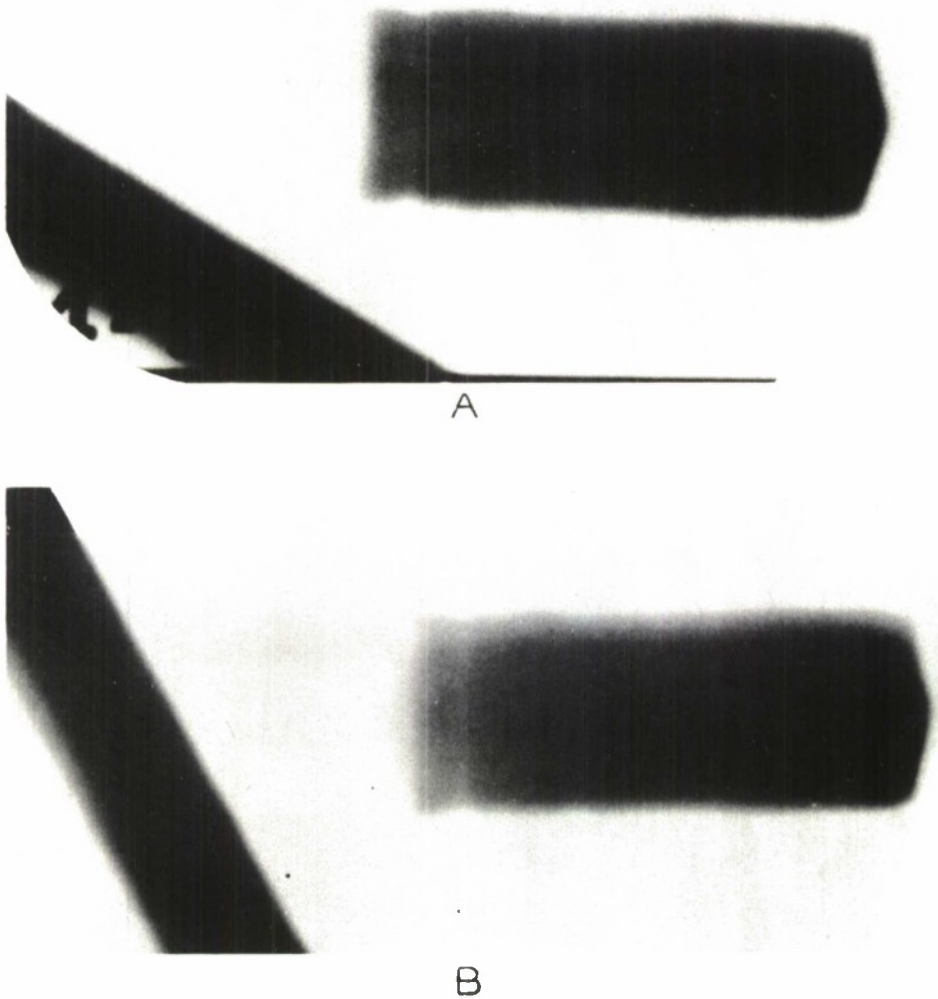


Figure 15. High-speed radiographs of Model 4 (R<sub>C</sub> 46) intact shell  
vs 5/8 inch plate

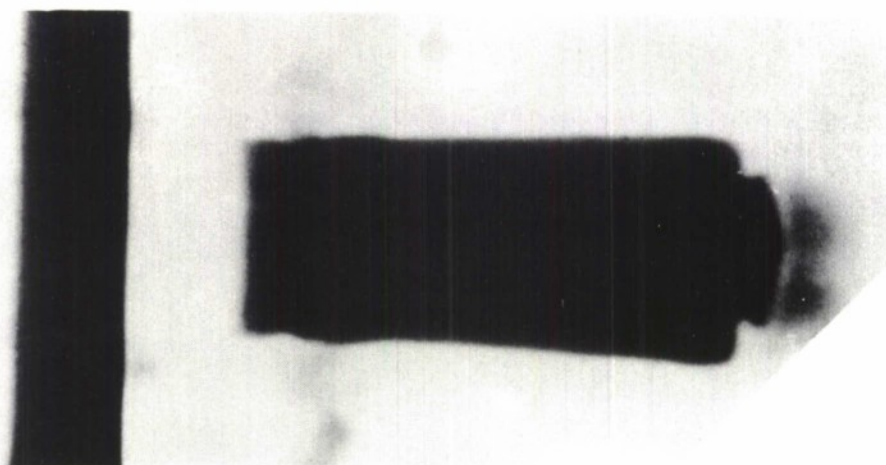
A - At 60°, 2890 fps

B - At 30°, 2890 fps

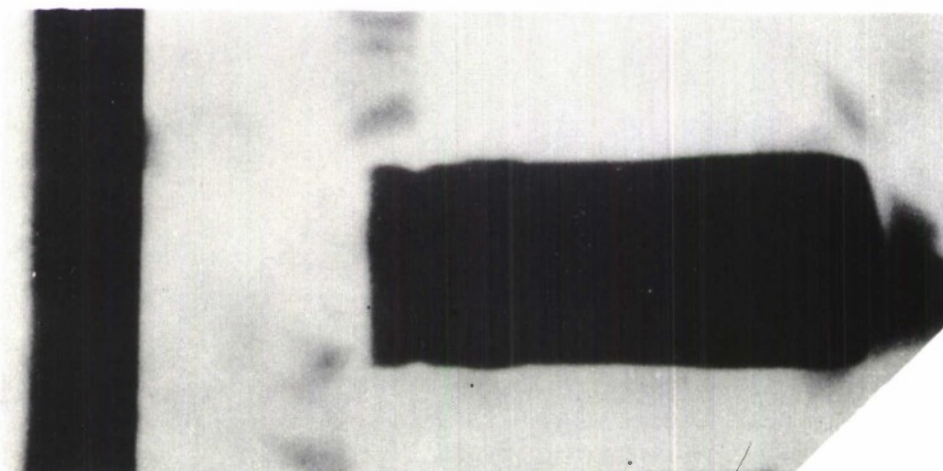
~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

Neg. #26240-15  
R-1275



A



B

Figure 16. High-speed radiographs of Model 4 shell vs 5/8 inch plate at 0°

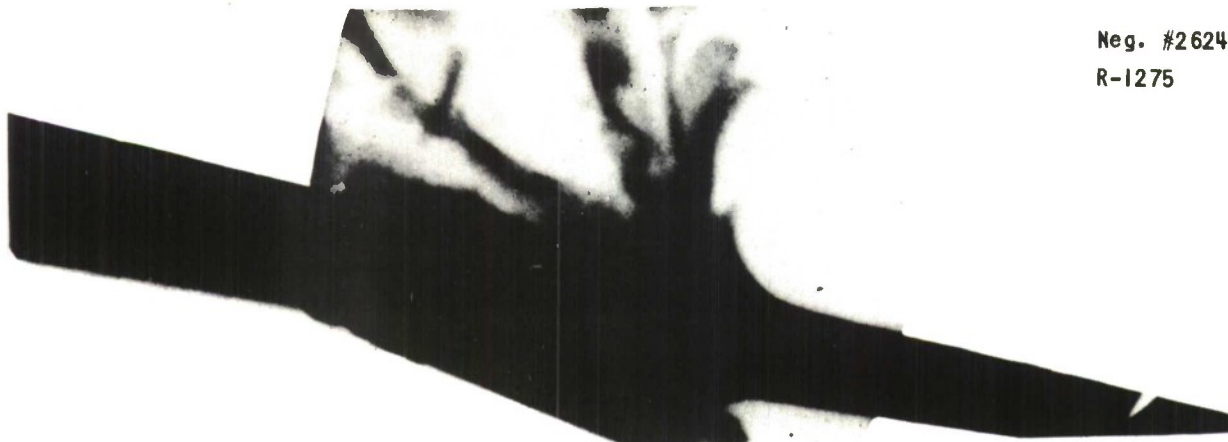
- A - Model 4 ( $R_C$  56), fracture started, 2907 fps
- B - Model 4 ( $R_C$  40), intact, 2857 fps

~~CONFIDENTIAL~~

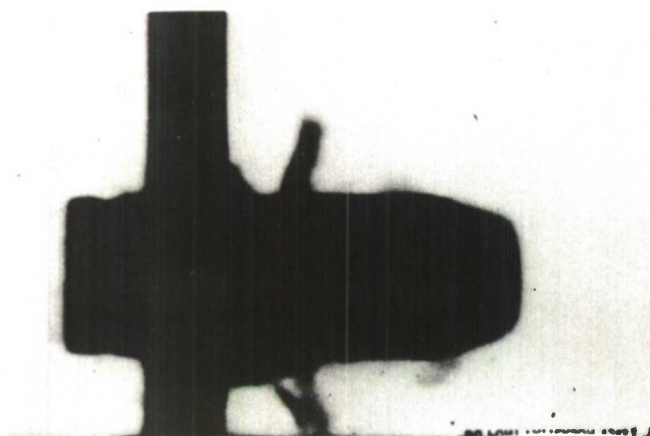


~~CONFIDENTIAL~~

Neg. #26240-16  
R-1275



A



B



C

Figure 17. High-speed radiographs of Model 4 shell vs 1/2 inch plate

- A - Model 4 (R<sub>C</sub> 46), intact; incomplete penetration at 2890 fps, 80°
- B - Model 4 (R<sub>C</sub> 56), fracture started at 2899 fps, 0°
- C - Model 4 (R<sub>C</sub> 56), intact at 2899 fps, 0°

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

Table V. Summary of Results for Model 4

| Target             |                    | Rounds<br>Fired | Striking<br>Velocity<br>(fps) | Hardness<br>R <sub>c</sub> | Condition<br>of<br>Projectiles             |
|--------------------|--------------------|-----------------|-------------------------------|----------------------------|--|
| Thickness<br>(in.) | Obliquity<br>(deg) |                 |                               |                            |  |
| 3/4                | 70                 | 1               | 2907                          | 56                         | Intact, no swell                           |
|                    | 70                 | 1               | 2915                          | 51                         | Intact, very slight swell                  |
|                    | 70                 | 1               | 2841                          | 46                         | Intact, slight swell                       |
|                    | 70                 | 1               | 2865                          | 40                         | Intact, slight swell                       |
|                    | 60                 | 1               | 2899                          | 56                         | Intact, no swell                           |
|                    | 60                 | 1               | 2882                          | 51                         | Intact, slight swell                       |
|                    | 60                 | 1               | 2907                          | 46                         | Intact, very slight swell                  |
|                    | 60                 | 1               | 2907                          | 40                         | Intact, swell                              |
|                    | 45                 | 1               | 2899                          | 56                         | Intact                                     |
|                    | 45                 | 1               | 2924                          | 51                         | Intact, swell                              |
|                    | 45                 | 1               | 2907                          | 46                         | Intact, swell                              |
|                    | 45                 | 1               | 2865                          | 40                         | Intact, swell                              |
|                    | 0                  | 1               | 2941                          | 56                         | Fracture                                   |
|                    | 0                  | 2               | 2937                          | 46                         | Fracture                                   |
| 5/8                | 80                 | 1               | 2882                          | 56                         | Intact, incomplete perforation             |
|                    | 75                 | 1               | 2899                          | 56                         | Intact, no swell                           |
|                    | 75                 | 1               | 2907                          | 51                         | Intact, no swell                           |
|                    | 75                 | 1               | 2915                          | 40                         | Intact, no swell                           |
|                    | 70                 | 2               | 2907, 2941                    | 56                         | Intact, no swell                           |
|                    | 70                 | 2               | 2933, 2941                    | 46                         | Intact, slight swell                       |
|                    | 65                 | 4               | 2833, 2840,*                  |                            |  |
|                    |                    |                 | 2940,* 2941                   | 56                         | Intact, no swell                           |
|                    | 65                 | 4               | 2841, 2841,                   |                            |  |
|                    |                    |                 | 2933, 2941                    | 46                         | Intact, slight swell                       |
|                    | 60                 | 2               | 2841, 2833                    | 56                         | 1 - intact, swell;<br>1 - intact, no swell |
|                    | 60                 | 2               | 2865, 2890                    | 46                         | Intact, slight swell                       |
|                    | 30                 | 1               | 2915                          | 56                         | Intact, slight swell                       |
|                    | 30                 | 1               | 2907                          | 51                         | Intact, swell                              |
|                    | 30                 | 1               | 2890                          | 46                         | Intact, swell                              |
|                    | 30                 | 1               | 2907                          | 40                         | Intact, swell                              |
|                    | 0                  | 2               | 2907, 2915                    | 56                         | Fracture started                           |
|                    | 0                  | 1               | 2899                          | 51                         | Fracture started                           |
|                    | 0                  | 2               | 2899, 2915                    | 46                         | Split in half                              |
|                    | 0                  | 1               | 2857                          | 40                         | Intact, swell                              |
| 1/2                | 80                 | 1               | 2890                          | 46                         | Intact, incomplete perforation             |
|                    | 75                 | 1               | 2870                          | 46                         | Intact                                     |
|                    | 0                  | 2               | 2899                          | 56                         | Fracture                                   |
|                    | 0                  | 2               | 2899, 2882                    | 46                         | Intact, slight swell                       |

\*Estimated

~~CONFIDENTIAL~~

This shell design is exceptionally good for all obliquities between 30 and 75 degrees. To improve its performance at 0° obliquity, the flat end could be made smaller, and lower hardnesses could be tried to find the optimum hardness. To improve its performance at the very highest obliquity, the forward portion should be made to approach a cylinder more closely. However, a modification of this type might make the shell behave like Model 3.

#### CONCLUSIONS

1. A solid nose, base fuze 30 mm shell has been designed which is at least twice as effective for penetration as the present nose fuze design (T306E10) against 60° and 70° obliquity aluminum armor targets. The shell practically satisfies the original penetration requirements.

2. It is possible for the shell to remain intact after defeating 3/4 inch 24S-T4 aluminum alloy plate between 45° and 70° obliquities and 5/8 inch plate from 0° to 75° obliquities at velocities of 2800 to 3000 fps.

#### FUTURE WORK

While this inert loaded shell practically satisfies the original penetration requirements, it does not conform to the exterior contours required for the gun. A modification of this shell, which approaches these requirements, has been made. Shell of this design will be tested against various target conditions, and flash radiographs will be taken of them after penetration to observe their performance and to find ways of improvement, under the restrictions of exterior contour, explosive capacity, and total weight.

#### RECOMMENDATIONS

It is recommended that the blunt nosed principle of design be considered for other types of HE and small arms armor piercing ammunition.

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

## Distribution

- 1 - Chief of Ordnance  
Department Army  
Washington 25, D. C.  
Attn: ORDTX-AR
- 2 - Attn: ORDTS
- 1 - Attn: ORDIM
- 1 - Attn: ORDTB
- 1 - Commanding Officer  
Springfield Armory  
Springfield 1, Mass.  
Attn: Eng Dept
- 1 - Commanding General  
Picatinny Arsenal  
Dover, New Jersey  
Attn: Tech Group
- 1 - Commanding Officer  
Rock Island Arsenal  
Rock Island, Ill.  
Attn: Laboratory
- 1 - Commanding Officer  
Watertown Arsenal  
Watertown 72, Mass.  
Attn: Tech Group
- 1 - Director  
Ordnance Materials  
Research Office  
Watertown Arsenal  
Watertown 72, Mass.
- 1 - Commanding Officer  
Lake City Arsenal  
Independence, Missouri  
Attn: H. W. Kline
- 1 - Commanding Officer  
Diamond Ordnance Fuze  
Laboratories  
Washington, D. C.
- 1 - Parke-Thompson Associates  
501 South Holmes  
Kirkwood 22, Missouri  
Attn: Div of Atlas Powder Co.
- 1 - Commanding Officer  
Kingsbury Ordnance Plant  
Laporte, Indiana  
Attn: O. C. Shannon
- 1 - Commanding General  
Ordnance Ammunition Center  
Joliet, Illinois  
Attn: E. T. Hackett
- 1 - Commanding General  
Aberdeen Proving Ground  
Maryland  
Attn: Lab Serv Div
- 1 - Attn: Ball Res Lab
- 1 - Attn: Tech Info Br, Bldg 313
- 2 - Attn: D & PS - Term Ball Lab
- 1 - Commandant  
U. S. Naval Proving Ground  
Dahlgren, Va.  
Attn: Term Ball Dept
- 5 - Armed Services Technical  
Information Agency  
Document Service Center  
Knott Building  
Dayton 2, Ohio  
Attn: DSC-SD  
(Code 1)
- 1 - Dr. C. W. Curtis  
Dept of Physics  
Lehigh University  
Bethlehem, Pa.
- 1 - Bulova Research and  
Development Laboratories, Inc.  
62-10 Woodside Avenue  
Woodside, New York  
Attn: O. B. Brockmeyer
- 1 - Hesse Eastern Corp.  
Cambridge 38, Mass.  
Attn: S. C. Hutchinson